



Solar System Exploration

2nd International Planetary Probe Workshop
August, 2004

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NASA Science Mission Directorate



Agenda

- Introduction
- Solar System Exploration
 - Highlights
 - Status of Programs
- Technology Drivers and Plans
- Summary



Highlights

Major accomplishments

- Genesis completed sample collection period April 26, and heads home
- MER successfully completed primary science mission April 26, and was approved to continue through Sep '04
- Robotic Lunar Exploration Program started, and 2008 Lunar Reconnaissance Orbiter AO released June 18
- Cassini-Huygens entered Saturn Orbit June 30th
- Independent review of Huygens probe release end to end events started
- 2 New Frontiers candidate missions selected July 15 for Φ A studies Discovery proposals received July 16 in response to March AO
- Kepler subsystems peer reviews started in preparation for PDR/NAR Oct
- Deep Impact full up system T/V testing completed successfully
- Dawn met all of its confirmation terms and conditions successfully
- MESSENGER was successfully launched



Highlights

Major Issues/Concerns

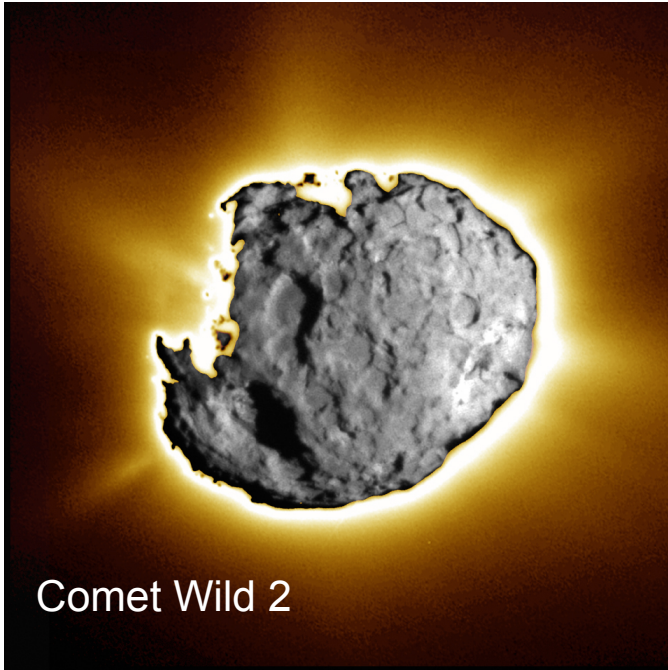
- New Horizons launch vehicle certification, launch approval, NEPA, LANL security/safety issue, typical of nuclear powered missions on low flight rate launch vehicles
- Re-establishing the Discovery/New Frontiers Program Office (now at MSFC)
- Reconciliation of full cost impact on programs
- Maintaining focus on priorities during re-organization
- “Pathways” for long term outer planets strategy
- Establishing a robust technology program that will keep up with the demands of future solar system exploration



Status of Operating Missions, and Infrastructure Elements in SSE



Stardust



Comet Wild 2 return of dust and interstellar particles for analysis in Earth laboratories

- Launch: Feb 1999
- Comet Wild 2 flyby: Jan 2 2004
- Earth return of samples: Jan, 2006
- Preliminary Eval of samples: Jul, 2006
- End of mission: Sep 2006

Status

- No technical or programmatic issues
- Preparations and review for Genesis sample return of great benefit to mission

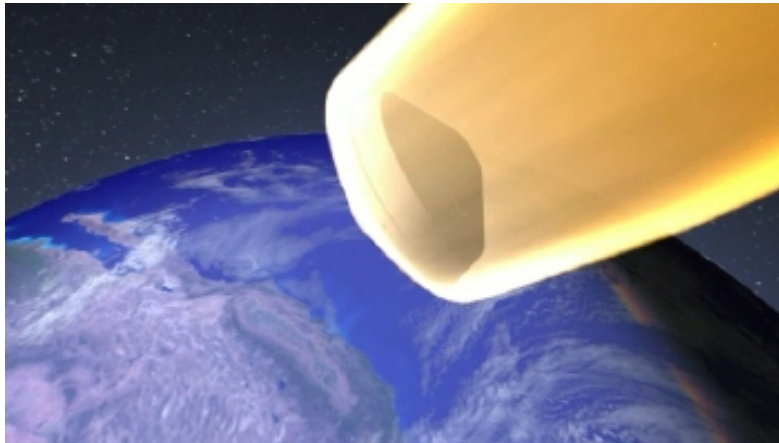


Genesis



Solar wind sample return

- First sample return since Apollo
- Level 1 requirement of 22 mos of sample collection complete
- End of sample collection: April 04
- Earth return of samples: Sep 04



Status

- Plans for sample capture and recovery Sept 8 proceeding well. Significant independent review

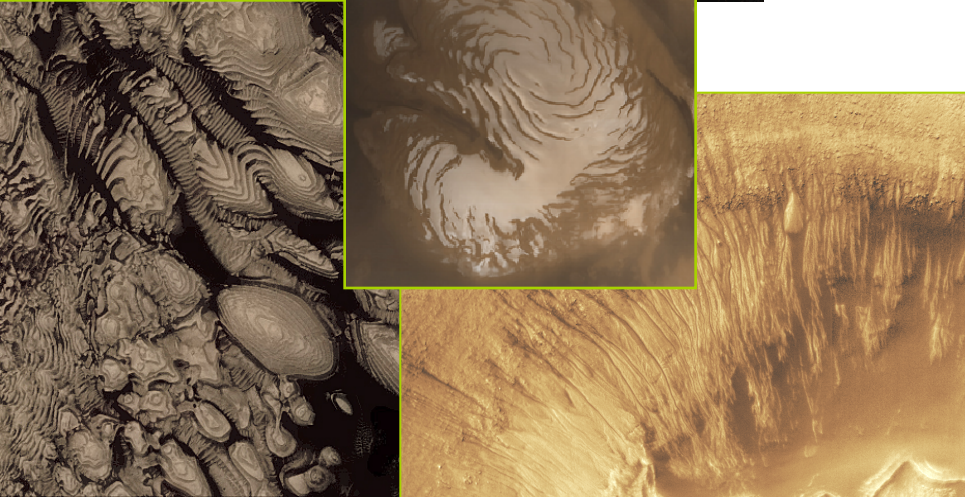


Mars Global Surveyor



Global visible, topographic and thermal emission spectra' data of Mars

- No operational, technical or programmatic issues
- Third mission extension starts Sep 2004

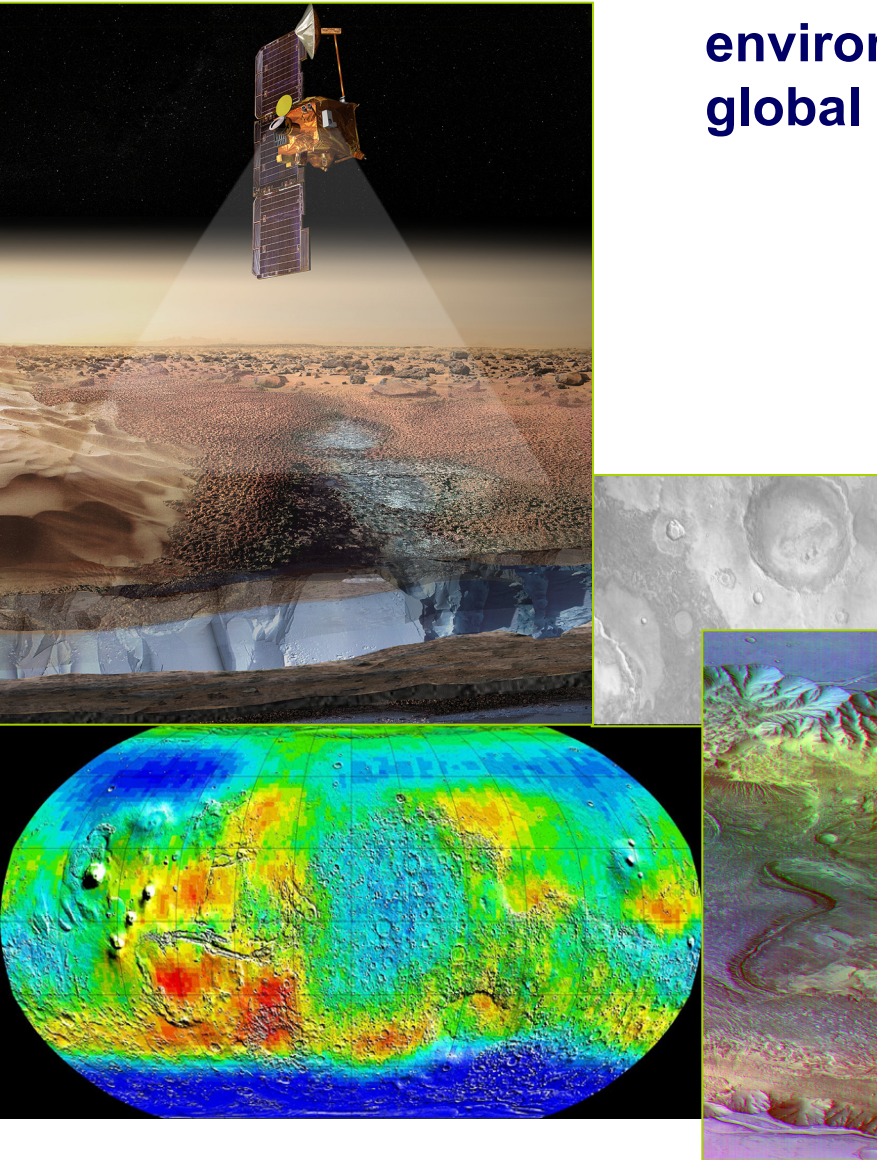




Odyssey

Mineralogy, thermal hot spots, and near environment radiation measurements at global scales, plus global composition

- No operational, or programmatic issues
- MARIE instrument not operating
- Mission extension starts Sep 2004





2003 Mars Exploration Rovers

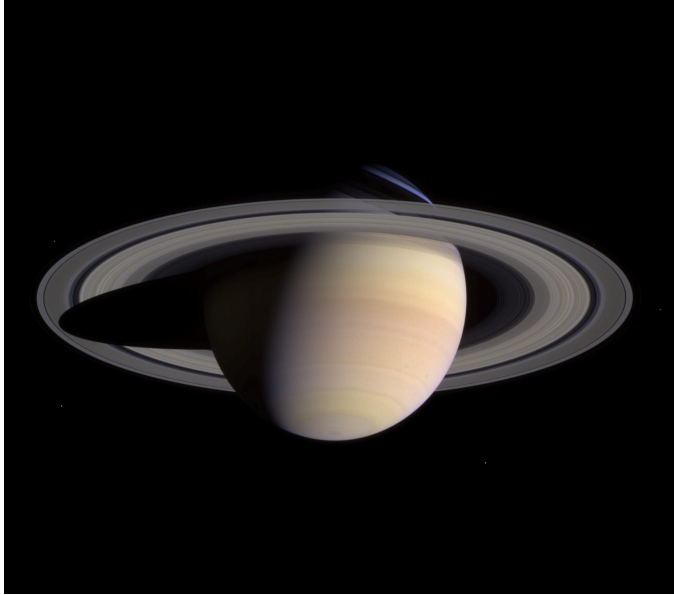


Determine the aqueous, climatic, and geologic history of 2 sites on Mars, searching for clues to habitability

- Primary mission completed successfully April 2004, meeting all level 1 requirements.
- Mission extended through September 2004, and projected to go several months beyond
- Spirit at Columbia Hills somewhat impaired by front wheel drawing higher than normal current.
- Opportunity inside “Endurance” crater



Cassini-Huygens



The Cassini Huygens mission is a four year comprehensive study of the Saturn system, its rings, icy satellites, magnetosphere, and Titan, the planets largest moon

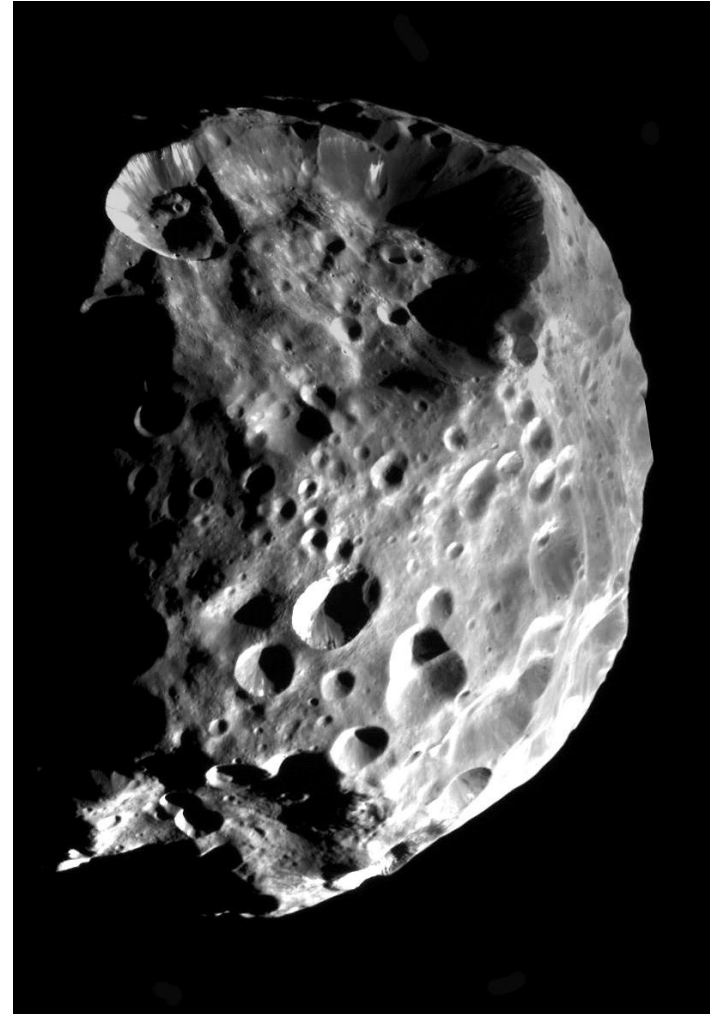
- 76 orbits around Saturn, 44 of which are close flybys of Titan
- Huygens probe release December 24, Arrival January 16

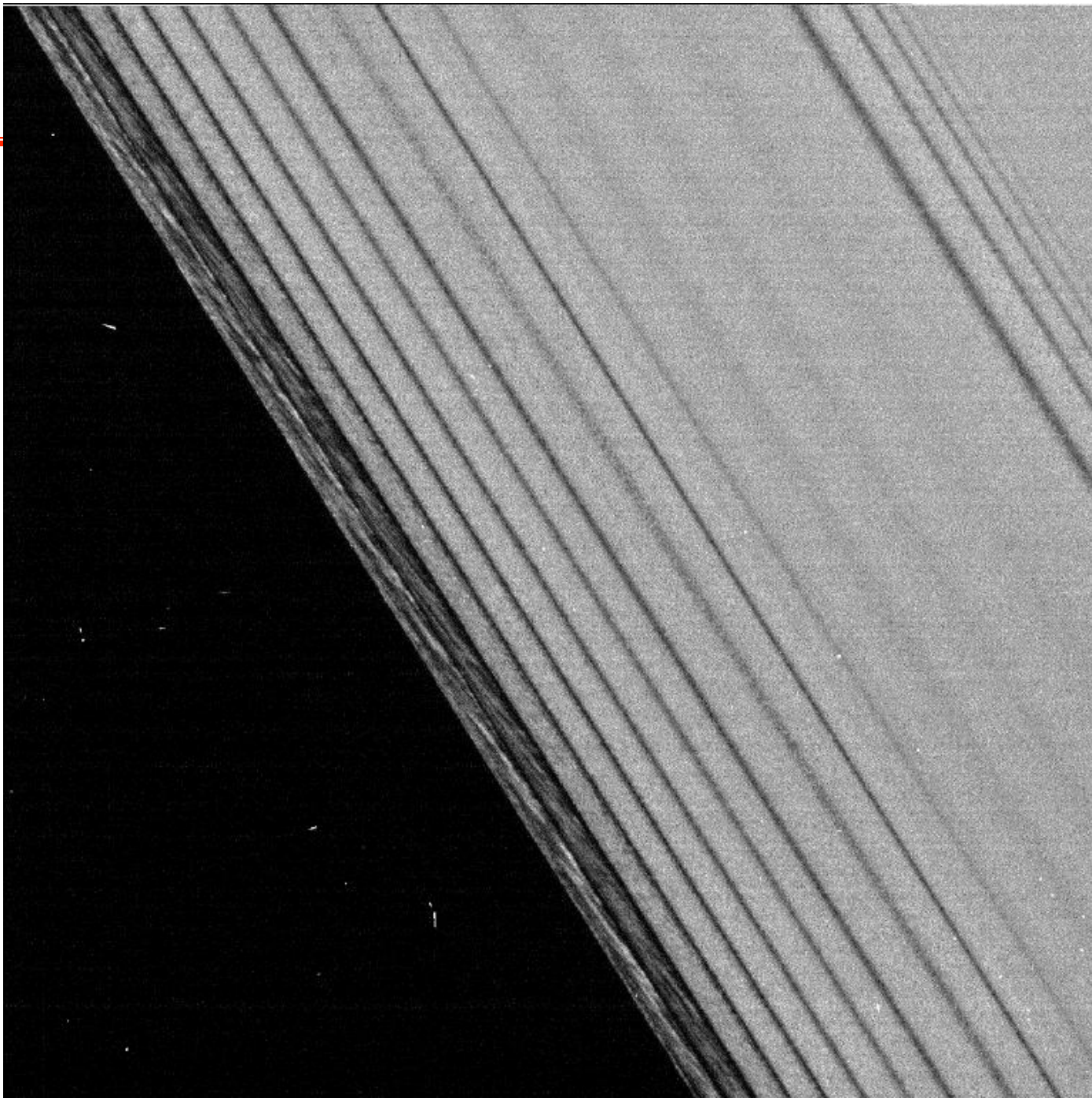
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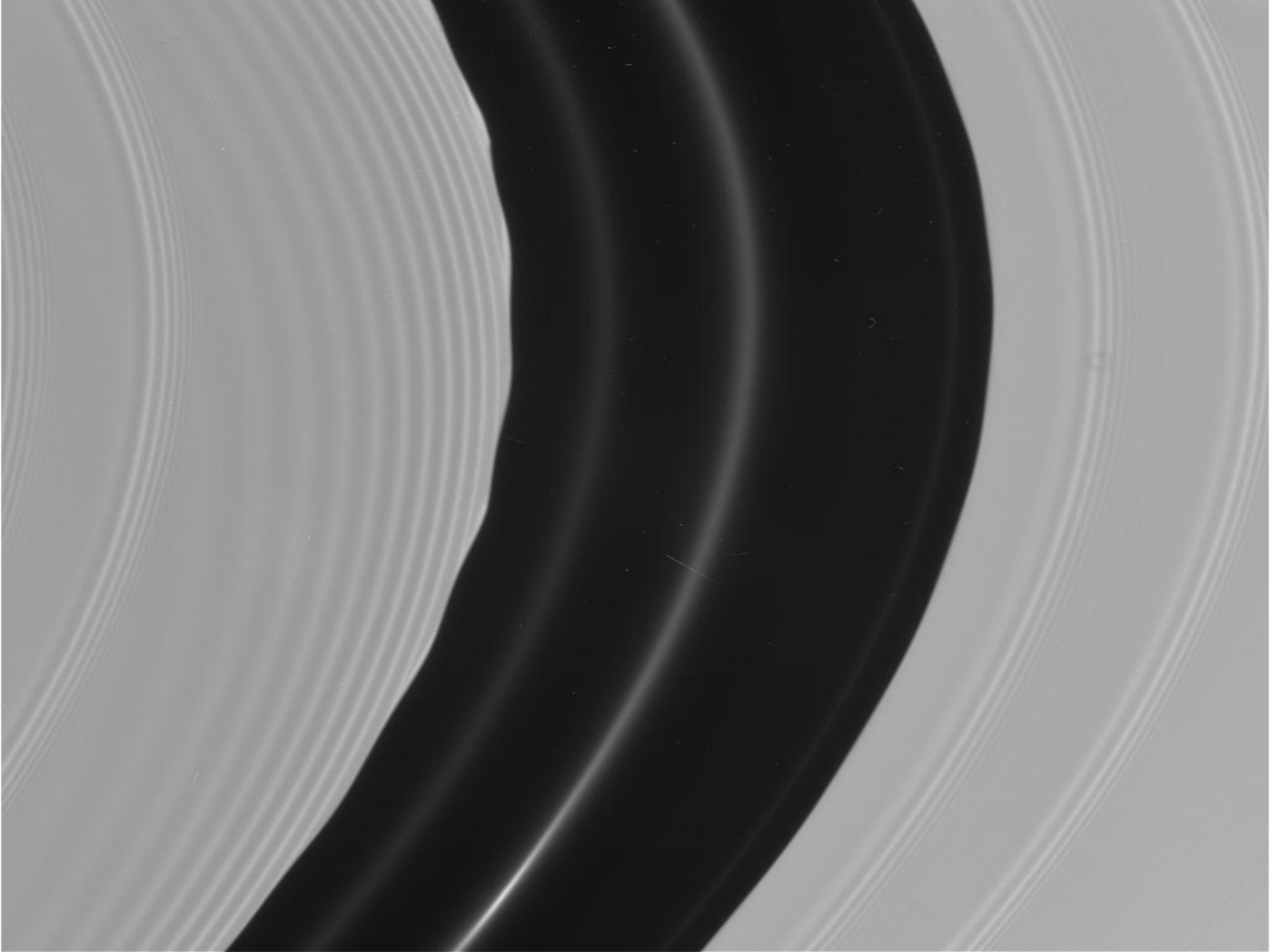
- Successful SOI June 30th. Observatory is healthy, but concerns remain about Huygens, due to uncertainty about Titan atmosphere. NASA/ESA independent review team assembled.
- Early science data shows great promise for a new chapter in outer planet science full of surprises

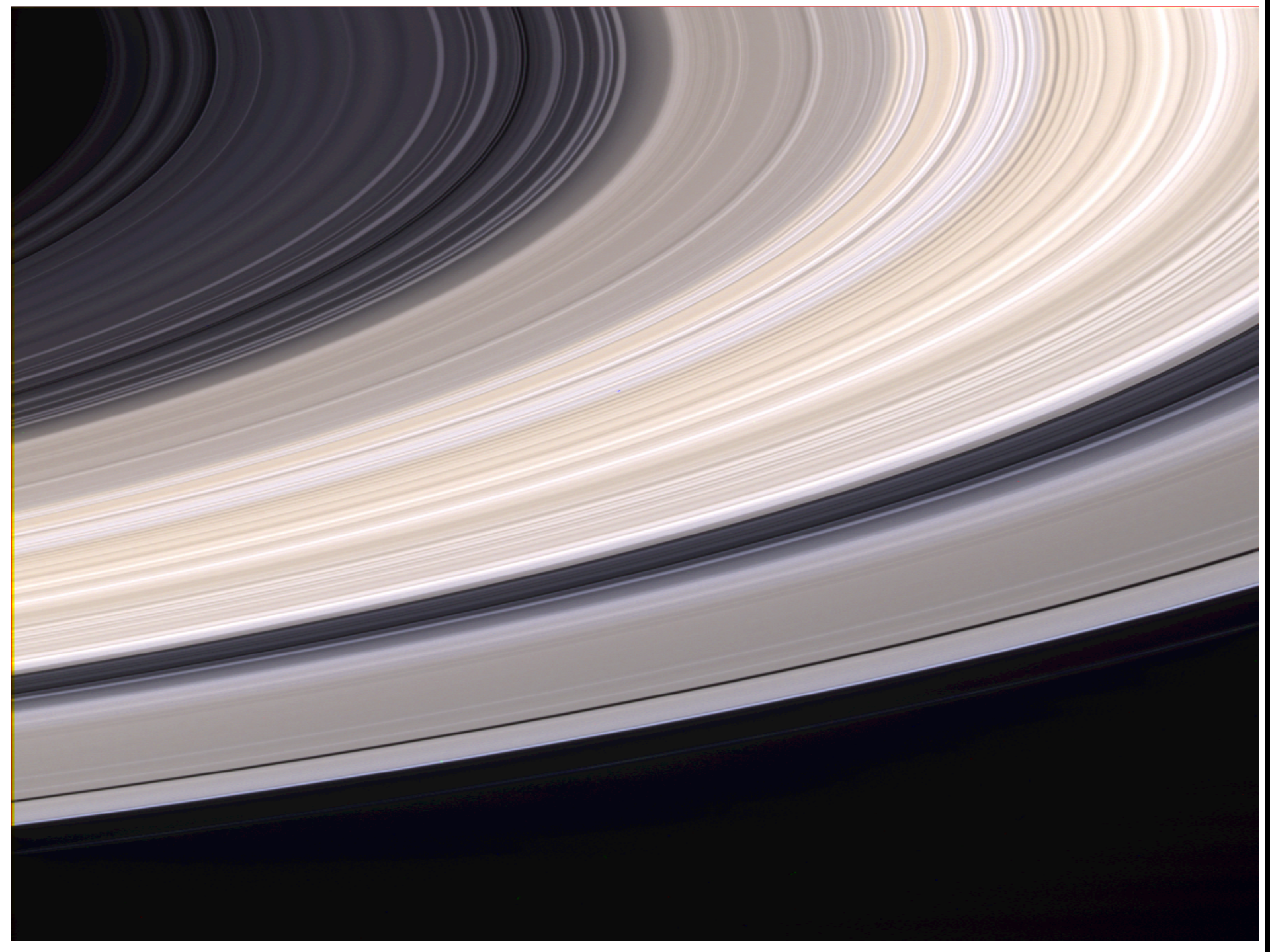


The Face of Phoebe



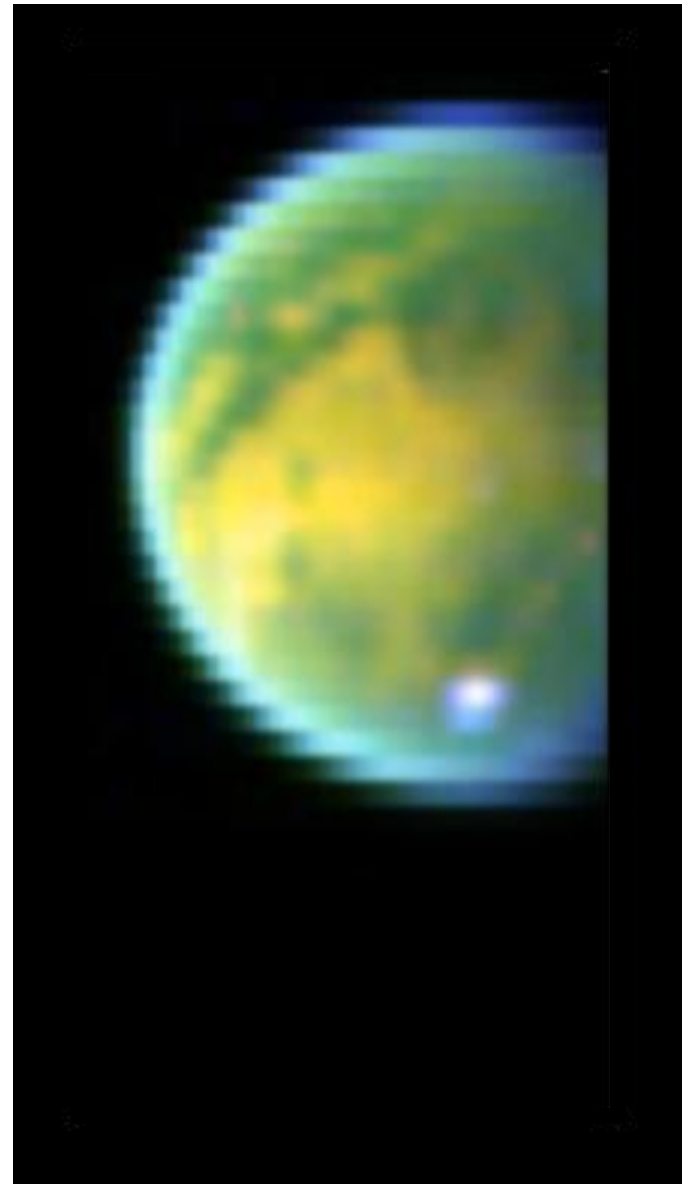
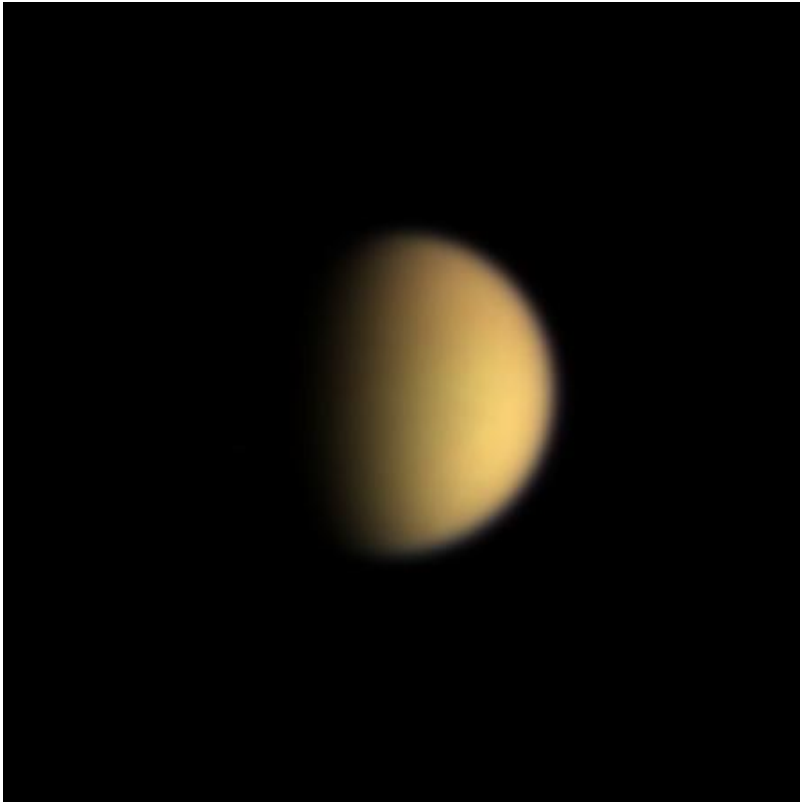








Titan





Deep Space Network



Status

- Reliability continues to be excellent with >98% data capture efficiency, and >96% for uplink
- Several actions being worked in response to findings of code S commissioned independent review board
 - Mid to long term strategic plan and program plan that reflects revamped DSMS due at end of calendar year

Current Assets and capabilities

18 antennas spread over 3 longitudes (S, X, and Ka band capability)

Future (to enable higher data rates), studies on RF arrays, and optical technology

Currently Supporting

12 HEO, Lunar, L1 & L2 missions, 13 Deep Space Missions, Orbital debris monitoring, Solar System Radar, Radio Science

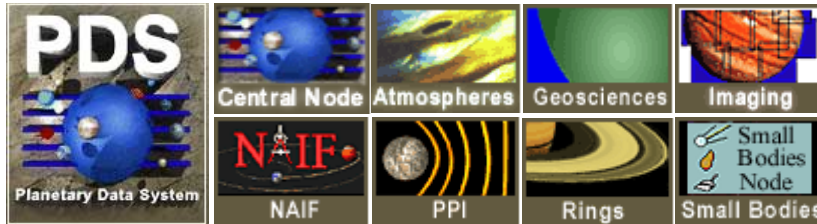


Planetary Data System

Status

Selection of new nodes completed

Independent review recommendations
assessment on going, and most pressing issues
being implemented



Major Functions

Curate planetary/solar system data

Provide the public with a readily accessible on-line archive of peer reviewed datasets

Provide tools, ancillary data, metadata to enhance community interpretation of datasets

Currently Supporting

Archive and maintenance of past mission datasets (restorations)

Archive of current mission datasets (pipeline)

Preparation for future missions (coordination of interfaces, standard evolution and enforcement, coaching)

Issues

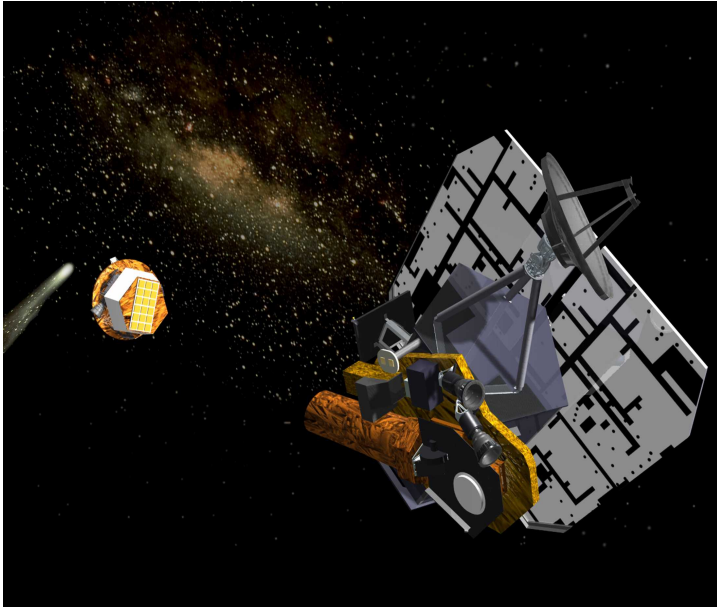
System evolving from a hard media archive to an on-line system



Status of Missions in Development in SSE



Deep Impact



Encounter and projectile impact investigates structure and composition of 9P/Tempel 1 comet nucleus

- Launch: December 30, 2004
- Encounter: July 4, 2005

Status

- Environmental testing/thermal proceeding well. Integrated spacecraft complete w only minor issues. Impactor T/V testing begun



MESSENGER



MESSENGER will collect images of the entire planet and gather highly detailed information on: Mercury's geological history, the nature of its atmosphere and magnetosphere, the makeup of its core, and the character of its polar materials

Launch
Earth flyby
Venus flybys
Mercury flybys

Mercury orbit

August 2004
July 2005
October 2006, June 2007
January 2008, October 2008,
September 2009
March 2011 - March 2012



Dawn

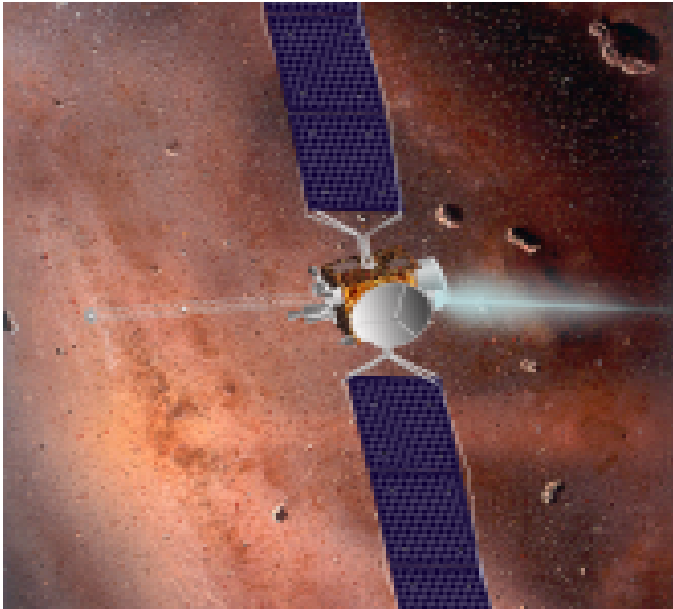


Image and measure geophysical properties of complementary bodies Vesta and Ceres

- ATLO start
- Launch: June 2006
- VESTA encounter
- CERES encounter

Status

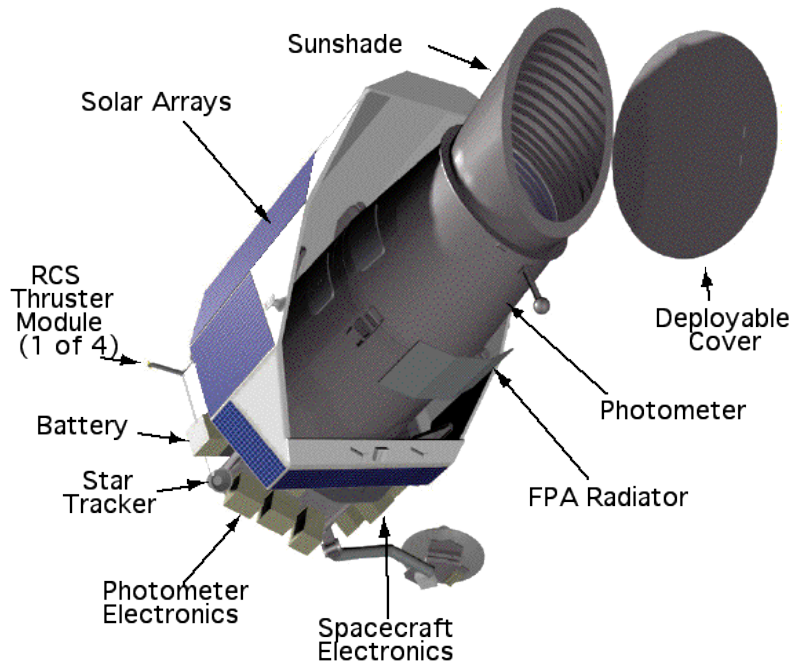
- Two gates established at confirmation review (mass reconciliation, and critical design) that focused on technical and programmatic margins passed successfully



Kepler

Determine the frequency and distribution of terrestrial planets in or near the habitable zones of solar-type stars

- Search ~ 100,000 stars for 4 years
- Look for transits
- Earth trailing orbit (like SIRTf)
- PDR October, 2004
- Launch in 2007



Status

- Preparations for Confirmation Review on schedule with subsystem PDR's begun in June



New Horizons



Characterize and Map the surface of Pluto and Charon, and Characterize the atmosphere of Pluto

- Draft Environmental Impact Statement complete:
- Start of ATLO: June 2004
- Launch: January 2006

Status

- ATLO started.
- LANL shut down threatens RTG production schedule
- Data book, launch vehicle certification, SRB qualification remains challenges to 2006 launch



2005 Mars Reconnaissance Orbiter



Climate, and high resolution mineralogy and morphology science at key sites

- CDR completed successfully on May 21-23
- ATLO start 5/04
- Launch Aug 2005

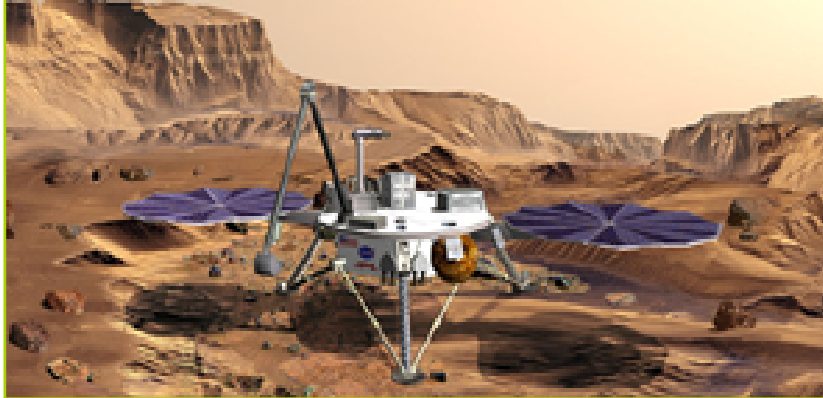
Status

- ATLO proceeding fairly well, but instrument schedule remains a threat



2007 Scout - Phoenix

Phoenix
Dr. Peter Smith, University of Arizona



Lander to ice-rich high northern latitudes to investigate chemistry, organics, and climate

- PDR- 12/1/04
- CDR- 9/01/05
- ATLO- 3/01/06
- Launch- 8/9-8/21/07 Window

Status

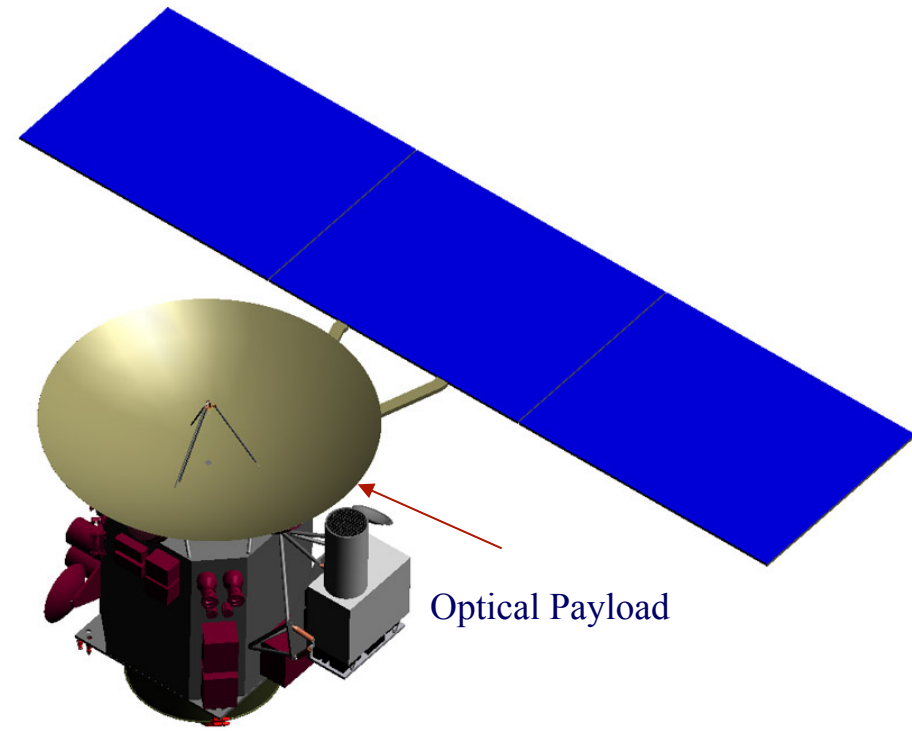
- Mission proceeding well, with no major technical or programmatic issues
- Level 1 requirements signed. Preparing for Preliminary Mission Systems Review (PMSR)



2009 Mars Telecom Orbiter

Dedicated communications relay (X, Ka, UHF, and Optical Technology Demo) satellite, providing ~80% of Mars every orbit with lifetime of 6 yrs in orbit (10 yrs consumables)

- Successful concept review last May
- Optical demo placing under control, but still a significant challenge
- Will release announcement for small science payload fall 2004

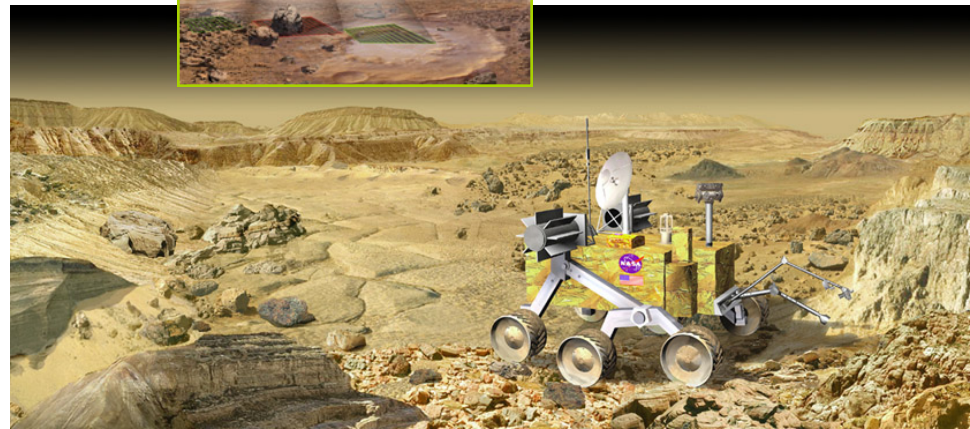
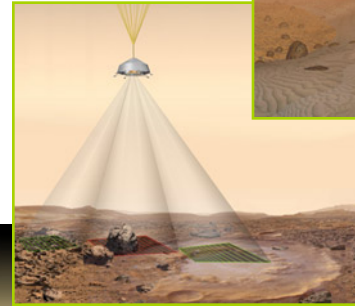
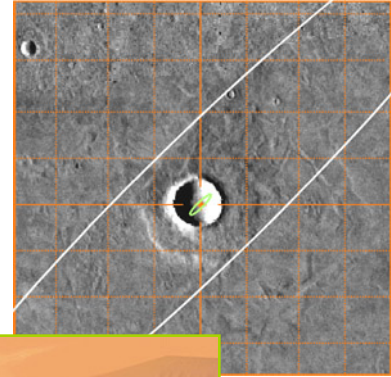




2009 Mars Science Laboratory

Search for habitable environments, and signs of building blocks of life

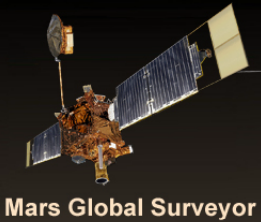
- PMSR Spring 05 — start Phase B
- PDR 1/06 — start Phase C/D
- Launch 10/09
- Concept review scheduled for November. P. Theisinger assigned as Project Manager. Several trades in work to fit within budget available
- Proposals received for instruments. Selection expected 10/04



Mars Exploration Program

Launch Year

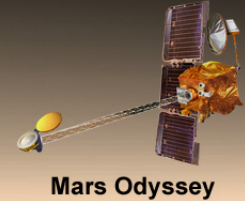
OPERATIONAL



Mars Global Surveyor

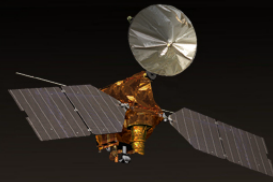


ESA
Mars Express



Mars Odyssey

2005



Mars
Reconnaissance
Orbiter
(Italian SHARAD)

2007

Completed Scout Mission



Phoenix

2009



Mars Telesat

Science pathways
responsive to discovery

Mars Science
Laboratory



...Next Decade

Explore the
Evolution of Mars

Search for
Evidence of Past Life

Search for Present Life

Explore
Hydrothermal
Habitats

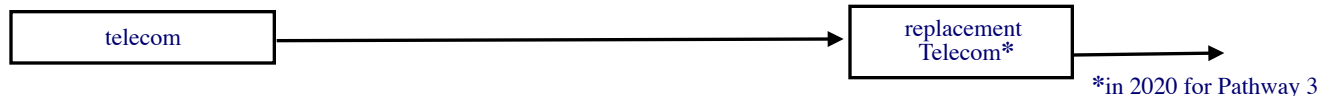
Science Pathways and Mission Sequences

A Transition from “Follow the Water” to “Follow the Carbon”

Advance Knowledge, and Technology in Preparation for Human Exploration

| Pathway | 2009 | 2011 | 2013 | 2016 | 2018 | 2020 | NOTES |
|---|-------------------------------|-------|-------------------------------|----------------|--------------------------------------|------------|--|
| Search for Evidence of Past Life | MSL to Low Lat. | Scout | Ground-Breaking MSR | Scout | Astrobiology Field Lab or Deep Drill | Scout | All core missions to mid-latitudes. Mission in '18 driven by MSL results and budget. |
| Explore Hydrothermal Habitats | MSL to Hydrothermal Deposit | Scout | Astrobiology Field Laboratory | Scout | Deep Drill | Scout | All core missions sent to active or extinct hydrothermal deposits. |
| Search for Present Life | MSL to N. Pole or Active Vent | Scout | Scout | MSR with Rover | Scout | Deep Drill | Missions to modern habitat. Path has highest risk. |
| Explore Evolution of Mars | MSL to Low Lat. | Scout | Ground-Breaking MSR | Aeronomy | Network | Scout | Path rests on proof that Mars was never wet. |

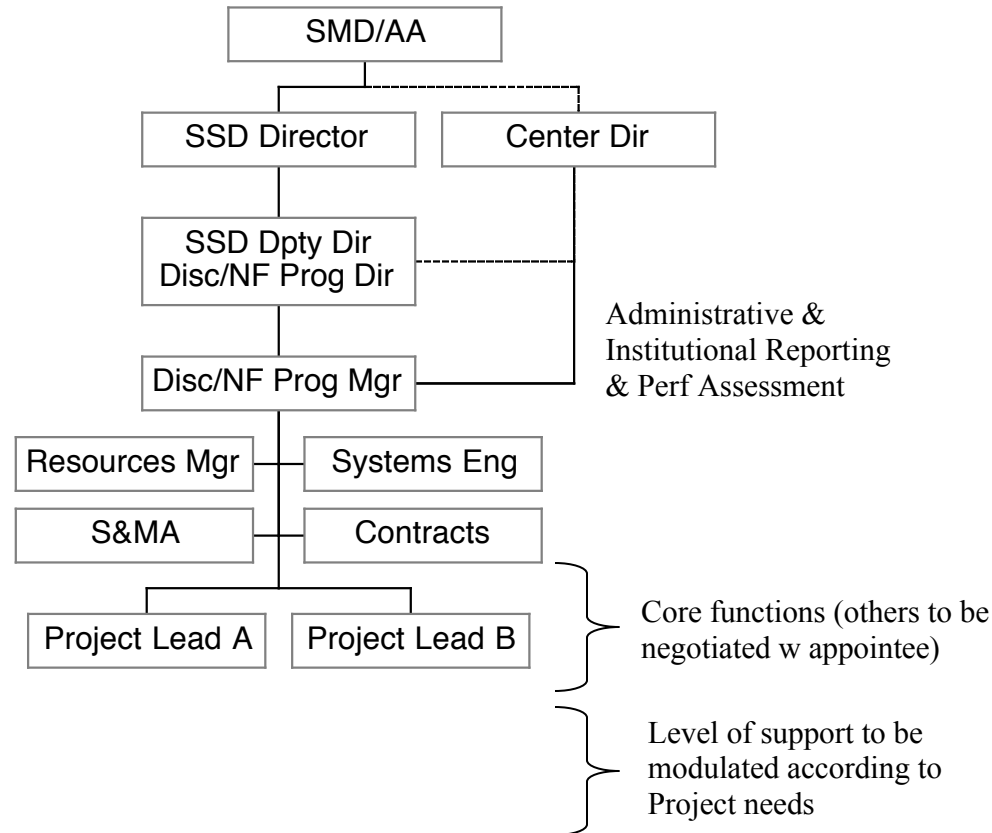
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|--------------------------------------|--|-----------------------------------|--|--------------|--|--------------|--|
| 2005 President's Budget Augmentation | | Scout Safe on Mars/ISRU Lander | | Mars Testbed | | Mars Testbed | |
|--------------------------------------|--|-----------------------------------|--|--------------|--|--------------|--|



Note: The pathway to be followed will depend on knowledge and technologies developed this decade



Solar System Exploration Division Disc & New Frontiers Organization





Purpose of Discovery and New Frontier Programs

Provide frequent opportunities for the science community to propose full investigations conducted under a fixed price cost cap to address high priority objectives in solar system exploration

- Discovery
 - Scientifically un-restricted (except for Mars proper) full and open competition for \$360M class life cycle cost missions
 - AO released every 18 to 24 months
- New Frontiers
 - Addresses high priority investigations identified by the NAS in the Decadal Survey. Full and open competition for \$700M class life cycle cost missions
 - AO released every 3 to 4 yrs

An important goal of the programs is to broaden/increase diversity in engineering, technology and science communities



New Frontiers Program AO #2

- NF will accomplish the **Science** of highly-ranked missions from the Decadal Survey fitting in the medium mission category. Proposals received as follows”

2 South Pole Aitken Basin Sample Return (SPA-SR)

1 Jupiter Polar Orbiter with Probes (JPOP)

1 Venus In-situ Explorer (VISE)

1 Comet Surface Sample Return (CSSR)

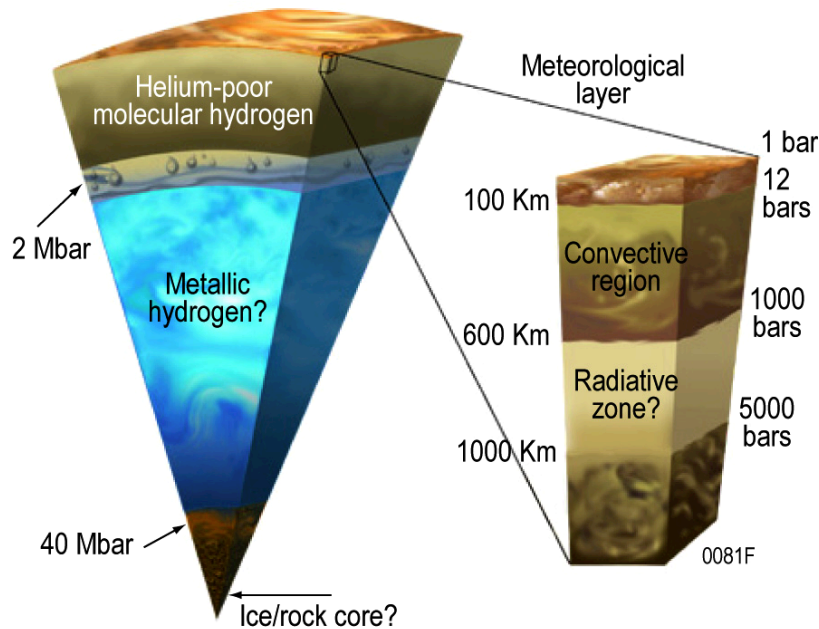
2 Missions of Opportunity proposals for ESA/Venus Express

- 2 candidate missions selected for phase A studies in July 15, 2004
- 7 month, \$1.2M phase A; 48 month B/C/D; launch by 30 June 2010 (31 December 2008 for MOs)



OSS- Solar System Exploration Division

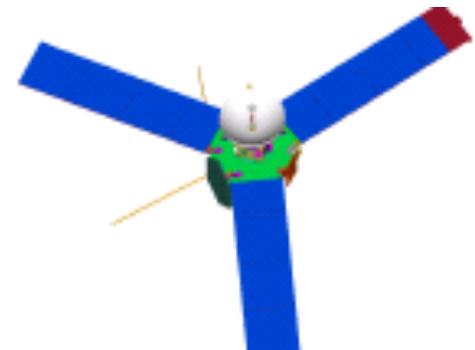
New Frontiers Mission 2 First Round Selections-**Juno**



Juno will measure:

- Gravity field to zonal harmonic 14
- Magnetic field to degree and order 14
- Brightness temperature at 6 microwave wavelengths
- The distribution of auroral electrons and ions
- Plasma waves

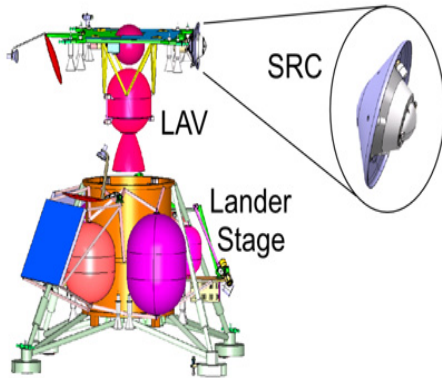
11 day elliptical ($1.063R_J$ - $40R_J$) polar orbit about Jupiter:





OSS- Solar System Exploration Division

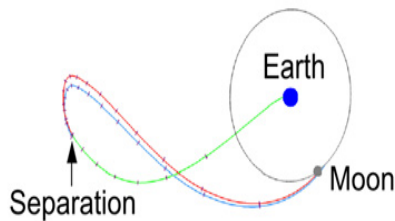
New Frontiers Mission 2 First Round Selections-**Moonrise**



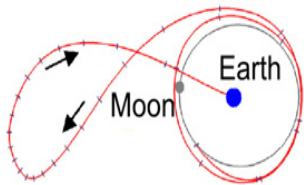
Moonrise Lander Spacecraft

Moonrise Science Objectives:

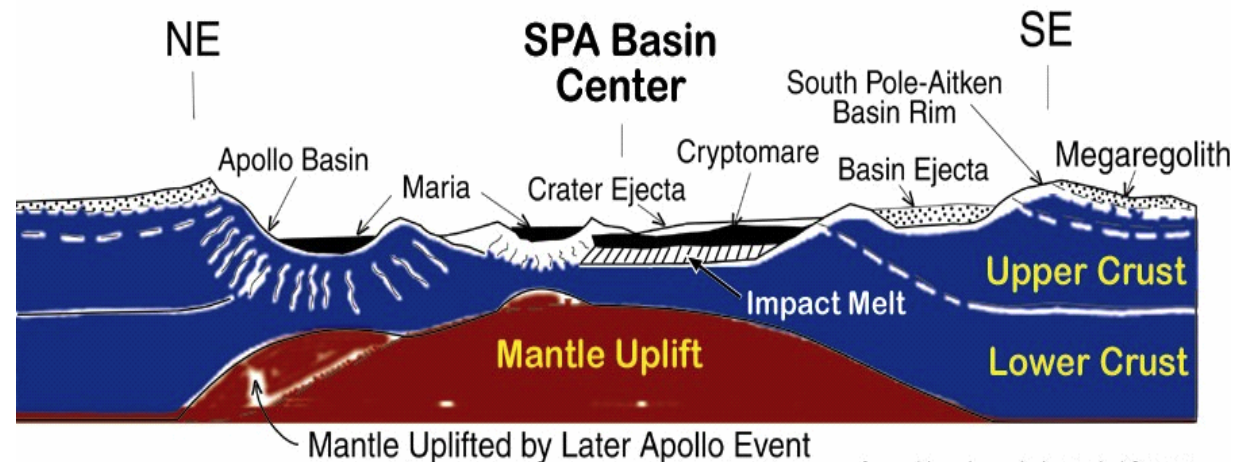
- Impact Chronology
- Crust/Mantle transition
- Giant basin Processes
- Thorium distribution
- Deep Mantle probes
- Gravity field of the lunar far side



EL1 trans-lunar trajectory



LL2 return trajectory



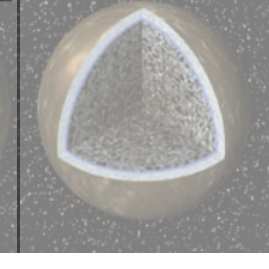
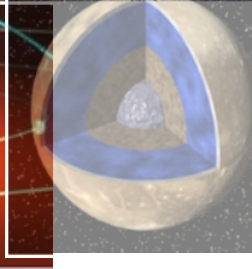
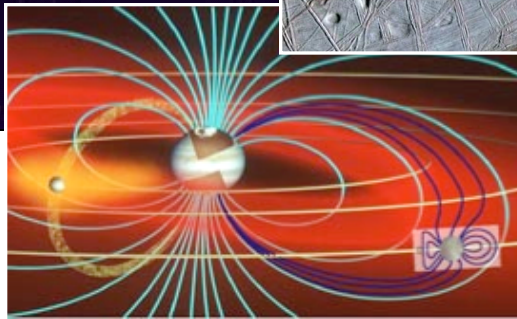
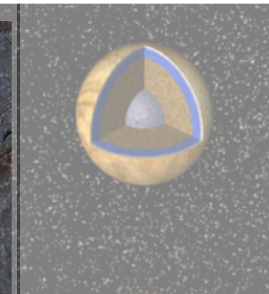
from Head et al. (1993) JGR 98.



Project Prometheus: Jupiter Icy Moons Orbiter

Global surface and subsurface characterization and exploration of the icy Galilean satellites

- SDT report complete to define spacecraft and mission requirements
- High Capability Instruments Tech development, and Outer Planets Fundamental Research Program underway
- Spacecraft Phase A Trade Studies underway
- RFP for phase B released





High Priority Technology Investment Areas

NASA's 2003 Solar System Exploration Roadmap defined thirteen "high priority investment areas" grouped into three broad areas:

- **Technologies of Broad Applicability:** Relevant to all missions and including propulsion, power, avionics, telecommunications and information technology
- **In Situ Exploration and Sample Return;** Includes Entry Descent Landing, Autonomous Mobility and other technologies needed for this class of mission
- **Science Instruments:** Components, devices and systems for remote sensing and in situ instruments



Current Technology Programs

- **SE funded programs for broad area technologies**
 - **Mars Technology Program (MTP)**
 - **RPS**
 - **In-Space Propulsion Program (ISP)**
 - **DSN Technology Program (communication technology)**
- **New Millennium Program – Focused on system and subsystem validation of technologies, many of which are critical to solar system exploration**
 - **Subsystem validation – ST6, ST8**
 - **System validation – ST7, ST9**
 - **In-Space propulsion is partnering on two ST-9 teams**
- **Instrument Technologies**
 - **Planetary Instrument Development and Definition Program (PIDDP)**
 - **Astrobiology Science and Technology for Exploring Planets (ASTEP)**
 - **Astrobiology Science and Technology Instrument Development (ASTID)**



State of Technology Development

- **Implementation of the technologies identified in the roadmap has been uneven**
 - **Technologies of broad applicability (power, propulsion, communications) have established programs with a few gaps, but have heavily relied on other Agencies in the past**
 - **In Situ exploration and Sample Return technologies have little support except that provided through the Mars program**
 - **Science instrument technologies have significant programs. However, core programs in device technologies are under threat with the transfer of MSM**
- **Transfer of MSM from former Code R to Exploration Systems has created major uncertainties.**
 - **Several programs important to SSE are threatened.**
 - **May have to accept that technologies not tied to human robotic relationship will not be supported by Exploration Systems**
 - **Within that constraint some fruitful opportunities for collaboration may exist but will need to be aggressively pursued**



New Technology Planning Cycle

Changes in the Landscape

- **New programmatic developments since the last roadmap**
 - **President's vision for space exploration**
 - **Integration of existing solar system exploration effort with established focused Mars Program and newly formed Lunar initiative under one command**
- **New scientific results and experience in using new technologies in solar system exploration**
 - **Mars Exploration Rover**
 - **Successful sampling/return from Genesis and Stardust**
 - **Cassini Huygens**
- **Lessons learned from the development of Messenger, Deep Impact and Dawn**
- **Lessons to be gleaned from the New Frontiers #2 and next Discovery competitions (what did or did not get proposed and why)**
- **New technology planning tools**
 - **Improved methods of measuring the impact of technology on a mission**
 - **New tools for conducting technology portfolio planning**
- **SE is working with the new Science Mission Directorate leadership to establishment a more robust path for technology development and infusion**



Summary

- **Solar System Exploration has carried the exploration initiative with spectacular results over the last several years**
- **As the Agency moves forward in the robotic exploration of the Solar System, infusion of new technology will be mandatory for making the journey**
- **The Solar System Exploration community has a thorough understanding of the kinds of technologies that are of critical importance to enabling and enhancing missions aimed at addressing the existing Solar System Exploration Roadmap**
- **Changes in mission scope, addition of new mission objectives, and lessons learned from the Discovery, New Frontiers and Mars Scout competed programs necessitates a periodic review of these technology requirements**
- **New approaches to fostering and fielding technology may be needed to move forward**
- **Partnerships with the Exploration Directorate will need to be explored in order to maintain the momentum that existed with cooperative programs in the past**
- **Maintaining a strong linkage of a focused technology development program to the science objectives targeted, and the missions necessary to meet them, will ensure a technology program that is relevant and productive**